Laboratory Study on High-performance Lightweight Cement Slurries for Thermal Production Wells

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ABSTRACT

The main challenging cement slurry problems, such as weak formation with the pressure gradient of about 1.60 g/cm³, non-retrogressive compressive strength at 240 °C in steam stimulation and fast compressive strength development at about 18 °C in the wellhead, have been encountered in thermal production wells. To answer these challenges, the high-temperature resistant lightweight cement slurries with the densities of 1.40 g/cm³ and 1.50 g/cm³ were designed by choosing density reducer cenosphere and applying the high packing theory. These additives, such as retarder, fluid loss additive and accelerator, were also developed. The rheology, API fluid loss, compressive strength, free water and compressive strength stability in 240 °C were researched as well. The result showed that the properties of the cement slurries meet the need of the cementing job at 50 °C. The compressive strength on the top of the lightweight cement slurry column was more than 3.5 MPa after curing for 36h at 18 °C. The compressive strength was more than 30 MPa and did not regress after curing for 28d at 240 °C. The properties of the high-performance lightweight cement slurries could meet the requirements of the thermal production wells at 240 °C.

KEY WORDS: Cementing; heavy oil; lightweight cement slurry; high packing.

INTRODUCTION

Both the China’s increasing demand for energy and the decline of traditional oil and gas reserves have forced operators to go after unconventional resources. As an abundant and important unconventional resource, heavy oil could be an answer to the demand for energy. Thermal recovery technology, the most effective heavy oil exploitation way, is currently the largest and most mature applied EOR techniques of the world. The technology predominantly via steam huff and puff also with continuously applied steam flooding, electric heating and SAGD technology could benefit 1500×10⁴ tons of oil every year in China (Wang, 2010).

The main challenging cement slurry problems, such as weak formation with the pressure gradient of about 1.60 g/cm³, non-retrogressive compressive strength at 230 °C in steam stimulation and fast compressive strength development at about 18 °C in the wellhead, have been encountered in thermal production wells. The conventional lightweight cement slurries, however, usually developed low and retrogressive compressive strength, which limits their applications in cementing for heavy-oil reservoirs. In order to cope with these challenges, the high-tolerant lightweight cement slurries for 232 °C steam huff and puff of the thermal production wells, based on concept of high packing density, were invented by Schlumberger Oilfield Services in the late 20th century [Biosnault, 1999 and Al-Suwaidi, 2001]. In this paper, high-performance lightweight cement slurries for thermal production wells with the densities of 1.40 g/cm³ and 1.50 g/cm³ have been developed based on high-packing theory. The long-term compressive strength of set cements at 240 °C was also investigated.

EXPERIMENTAL

Materials. All materials were provided by the Boxing Company of China National Petroleum Offshore Engineering Co., Ltd.

Method. The performances of the cement slurries were determined according to API RP-2-10B-2013. The particle size distribution of a powdered lightweight strength enhancer PZW-T was recorded by OMEC LS-609 Laser Particle Analyzer. The properties of the cement slurries and the set cements were analyzed by Chandler Engineering instruments.

RESULTS

Development of additive agents for lightweight cement slurry

(1) Development of the powdered lightweight strength enhancer PZW-T. The principle of maximization the packing of the dry blends, based on concept of high packing density, has been applied successfully to design the high performance lightweight oil well cement slurries. The components of the dry blends with good size distribution are chosen to ensure the close compaction by reducing the water filled among the dry particles and water membrane around the particles. The good rheology is also obtained due to the “ball bearing” effect of the smaller particles. In the meantime, the components for dry blends are selected by the physical interaction and chemical reaction among various raw materials. In our experiments, a powdered lightweight strength enhancer PZW-T, composed of various materials with an...